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A

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): Hideki Tengeiji, Toshiya Endo and Yoshichi Otake

For: SOLID-STATE IMAGE SENSING APPARATUS AND METHOD OF IMAGE SETTING

Enclosed are:

X Specification, Claims and Abstract
X Seven (7) sheets of drawing(s) (one xerographic copy)
__ An Assignment of the Invention to ^
__ A certified copy of the Priority Document (Japanese Application No. 1999-264018)
__ An Associate Power of Attorney
__ A Verified Statement to Establish Small Entity Status Under 37 CFR 1.9 and 37 CFR 1.27
X A Declaration and Power of Attorney for Patent Application (unsigned)

The filing fee has been calculated as shown below:

			Small Entity			Other Than A Small Entity	
For:	No.Filed	No.Extra	Rate	Fee	Or	Rate	Fee
Basic Fee				$345.00			$690.00
Total Claims	5-20	0	x9	$		x18	$
Indep Claims	2-3	0	x39	$		x78	$
Multiple Dep. Claim Presented			130			+260	$
			Total			Total	$690.00

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___ Any patent application processing fees under 37 CFR 1.17
___ The Issue Fee set in 37 CFR 1.18 at or before mailing of the Notice of Allowance, pursuant to 37 CFR 1.311(b)
___ Any filing fees under 37 CFR 1.16 for presentation of extra claims

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the application of

HIDEKI TENGEIJI,
TOSHIYA ENDO and
YOSHICHI OTAKE

Serial No.

Filed

For SOLID-STATE IMAGE SENSING APPARATUS AND METHOD OF IMAGE SENSING

CERTIFICATE OF MAILING VIA EXPRESS MAIL

I hereby certify that the following correspondence was deposited with the United States Postal Service as Express Mail, postage prepaid, in an envelope addressed to:
Box PATENT APPLICATION,
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Washington, D.C. 20231,
on this 12th day of September, 2000

Norma J. Payerle, Secy. to Edward G. Greive
Express Mail Label No. **EL617153165US**

TRANSMITTAL SHEET

Enclosed are the following documents:

Specification, Claims and Abstract
Drawings (7 sheets)
Declaration and Power of Attorney (unsigned)
Form PTO-1082 (in duplicate)
Check in the Amount of $690.00
Certified Copy of Priority Document (Japanese Application No. 1999-264018)
Return Receipt Postcard

In the event that the enclosed fee is not sufficient, the Commissioner is hereby authorized to charge payment of any additional fees associated with this communication or credit any overpayment to Deposit Account No. 18-0987.

Respectfully Submitted,

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September 12, 2000

SOLID-STATE IMAGE SENSING APPARATUS AND METHOD OF IMAGE SENSING

BACKGROUND OF THE INVENTION

The present invention relates to image sensing using a solid-state image sensing apparatus. Particularly, this invention relates to image sensing using a solid-state image sensing apparatus with a function of shifting light from an object to shift pixels for enhancing resolution equivalent to the resolution of a solid-state image sensing apparatus having a larger number of pixels.

Video cameras with a digital still-photographing function and digital still cameras install a solid-state image sensing apparatus with a function of shifting light incident to a solid-state image sensing device from an object to shift pixels for enhancing resolution equivalent to the resolution of a solid-state image sensing apparatus having a larger number of pixels (called a pixel-shifting function hereinafter).

Illustrated in FIG. 1 is a timing chart of exposure and reading for a solid-state image sensing device with such a pixel-shifting function.

As illustrated in EXPOSURE TIMING, exposure of a charge-coupled device (CCD) as a solid-state image sensing device for the first frame starts at time t11, charges that have been stored on the CCD are discharged at time t12 by an electronic shutter that is ON (opened) at timing as illustrated in ELECTRONIC SHUTTER TIMING, and exposure starts again.

For progressive-scanning, charges stored on pixels are once transferred to a vertical transfer register at time t13. Then, at timing a1 as illustrated in READ TIMING, the charges are transferred to a horizontal transfer register and read out. The period from time t12 to time t13 is an exposure period c1. Charges stored on the CCD for this period are output as an image signal for the first frame.

Exposure of the CCD for the second frame starts at right after time t13, charges that have been stored on the CCD are discharged at time t14 by the electronic shutter that is ON (opened) at timing as illustrated in ELECTRONIC SHUTTER TIMING,

and exposure starts again. Charges stored on pixels are once transferred to the vertical transfer register at time 1t5. Then, at timing a2 as illustrated in READ TIMING, the charges are transferred to the horizontal transfer register and read out. The period from the time t14 to time t15 is an exposure period c2. Charges stored on the CCD for this period are output as an image signal for the second frame.

Before exposure for the second frame, light incident to the CCD from an object is shifted by one line in the vertical direction as illustrated in PIXEL-SHIFT TIMING.

The image signals read out at timing a1 and a2 illustrated in READ TIMING for the first and the second frames are combined by signal processing 25 and output for enhancing resolution equivalent to the resolution of a solid-state image sensing apparatus having a larger number of pixels.

Illustrated in FIG. 2 is another timing chart of exposure and reading for a solid-state image sensing device with a pixel-shifting function.

The higher the shutter speed, the shorter the exposure period for each frame as illustrated as c3 and c4 compared to the periods c1 and c2 shown in FIG. 1. This causes delay in charge storing starting time to the CCD as time t16 and time t17, compared to time t12 and time t14 shown in FIG. 1. Charges are, however, read at time t13 and time t15 at which frames terminate, the same as shown in FIG. 1.

Solid-state image sensing apparatus as described above perform charge-reading when each frame terminates, thus resulting in displacement of image in time as illustrated in "d" in FIGS. 1 and 2, even in photographing with high-speed shutter for avoiding blurry photos.

A shutter speed for CCDs as illustrated in FIG. 2 higher than that illustrated in FIG. 1 will not cancel the displacement of image "d" as discussed above due to a fixed shutter speed for CCDs.

Solid-state imaging apparatus with a pixel-shifting function having a large displacement of image "d" as discussed above produce blurry photos with a deteriorated image quality.

SUMMARY OF THE INVENTION

A purpose of the present invention is to provide an apparatus and a method of image sensing using a solid-state imaging device with a pixel-shifting function that achieve a high shutter speed with less blurry photos.

The present invention provides an image sensing apparatus including: a solid-state image sensing device to convert light from an object into an image signal; a shutter, provided between the object and the solid-state image sensing device, to expose the solid-state image sensing device to the light for a first exposure period and a second exposure period that directly follows the first exposure period, the first and the second periods being the same length in time, each exposure period for exposing the solid-state image sensing device to the light corresponding to one frame or one filed of the object; a shift mechanism, to shift a passage of the light that has passed the shutter and incident to the solid-state image sensing device in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period; and a processor to combine image signals converted for the first and the second exposure periods to generate a composite image signal.

Moreover, the present invention provides a method of image sensing using a solid-state image sensing device for converting light from an object into an image signal. The solid-state image sensing device is exposed to the light for a first exposure period and a second exposure period that directly follows the first exposure period. The first and the second periods are the same length in time. Each exposure period for exposing the solid-state image sensing device to the light corresponds to one frame or one filed of the object. A passage of the light incident to the solid-state image sensing device is shifted in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period. Image signals converted for the first and the second exposure periods are combined to generate a composite image signal.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a timing chart for explaining an operation of a conventional solid-state image sensing apparatus;

FIG. 2 is a timing chart for explaining another operation of a conventional solid-state image sensing apparatus;

FIG. 3 shows a block diagram of a preferred embodiment of a solid-state image sensing apparatus according to the present invention;

FIG. 4 illustrates a principle of pixel-shifting according to the present invention;

FIG. 5 is a timing chart for explaining the first preferred embodiment of an operation of a solid-state image sensing apparatus according to the present invention;

FIG. 6 is a timing chart for explaining the second preferred embodiment of an operation of a solid-state image sensing apparatus according to the present invention; and

FIG. 7 is a timing chart for explaining the third preferred embodiment of an operation of a solid-state image sensing apparatus according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments according to the present invention will be disclosed with reference to the attached drawings.

FIG. 3 shows a block diagram of a preferred embodiment of a solid-state image sensing apparatus according to the present invention.

Light from an object (not shown) is incident to a shutter mechanism 11 through a lens mechanism 10. The shutter mechanism 11 (one of the important elements of this invention) is a mechanical shutter operated by a user via a shutter release button 14.

The light that has passed through the shutter mechanism 11 is further incident to an imaging circuit 13 through a pixel-shift mechanism 12. The imaging circuit 13 is provided with a CCD, a vertical transfer resister and a horizontal transfer resister.

The light incident to the imaging circuit 13 is converted

into an image signal by photo-to-electric conversion under the control by a timing signal fed by a timing signal generator (TG) 18. The image signal is supplied to a signal processor 19.

The shutter mechanism 11 and the pixel-shift mechanism 12 are controlled by a microprocessor (MPU) 15 via drivers 16 and 17, respectively, in response to the operation of the shutter release button 14.

As illustrated in FIG. 4, the pixel-shifting mechanism 12 is provided with an optical low-pass filter having a glass plate that is shifted between two positions 21a and 21b.

This shifting causes displacement of light passing through the optical low-pass filter by an angle δ (= $\{(1 - n)/n\} \cdot \sin(i) \cdot t$) where "i" is a rotary angle from the position 21a to 21b, and vice versa, and "n" is a refraction index. The rotary angle "i"-setting offers displacement of a passage of the incident light by one line to the CCD.

The operation as the first preferred embodiment of the solid-state imaging apparatus according to the present invention will be described with reference to FIGS. 3 and 5.

When a user presses the shutter release button 14 for photographing a still object, light from the object is incident to the imaging circuit 13 through the lens mechanism 10, shutter mechanism 11 and pixel-shifting mechanism 12.

As illustrated in EXPOSURE TIMING of FIG. 5, charges are stored on the CCD from just after time t1 that is a starting moment of the first frame, discharged at time t2 by an electronic shutter of the CCD, that is ON (opened) as illustrated in ELECTRONIC SHUTTER TIMING, and stored again.

At time t3 that is a terminating moment of the first frame, all the charges stored on the CCD are transferred to the vertical transfer register of the imaging circuit 13. The charges are further transferred to the horizontal transfer register of the imaging circuit 13 and read out.

As disclosed, an image signal for the charges stored from time t2 to time t3 is read out at a read timing a1 as illustrated in READ TIMING; and hence the period from time t2 to time t3 is an exposure period 6.

After time t3, the MPU 15 controls the pixel-shift mechanism 12 via the driver 17 so that the light incident to the CCD is shifted by one line in the vertical direction, as illustrated in PIXEL-SHIFT TIMING of FIG. 5.

The MPU 15 also controls the shutter mechanism 11 via the driver 16 to shut out the light from being incident to the CCD at time 4 after time passes the same period as the exposure period 6, or the exposure period 7. The light is prevented from being incident to the CCD at and after time t4.

Charges for the second frame are stored on the CCD of the imaging circuit 13 for the period from time t3 to time t4. The charges are kept at time t4 because no light is incident to the CCD after time t4, so that no charges are stored on the CCD, thus causing no overflow, resulting in no discharging operation.

All the charges that have been stored on the CCD are transferred to the vertical transfer register at time t5 at which the second frame terminates under the control by a timing signal fed by the TG 18. The charges are further transferred to the horizontal transfer register and read out.

As disclosed, an image signal for the charges stored from time t3 to time t4 is read out from the imaging circuit 13 at time t5, or a read timing a2 as illustrated in READ TIMING; and hence the period from time t3 to time t4 is an exposure period 7 as illustrated in EXPOSURE TIMING, by the mechanical shutter whose timing is illustrated as MECHANICAL SHUTTER TIMING.

The image signals for the fist and the second frames are supplied to the signal processor 19 and combined as an output composite imaging signal, as illustrated in SIGNAL PROCESSING 5.

In this embodiment, the displacement "d" of the image signals in time for the fist and the second frames corresponds to the exposure time 6 from time t2 to time t3, which is shorter than those shown in FIGS. 1 and 2, thus avoiding blurry photos.

Next, the operation as the second preferred embodiment of the solid-state imaging apparatus according to the present invention will be described with reference to FIG. 6. A shutter speed is higher in the second embodiment than that in the first

embodiment.

At time t1 illustrated in EXPOSURE TIMING of FIG. 6, that is a starting moment of the first frame right after a user presses the shutter release button 14, charges are stored on the CCD of the imaging circuit 13, discharged at time t6 by the electronic shutter of the CCD, that is ON (opened) as illustrated in ELECTRONIC SHUTTER TIMING, and stored again. The time t6 in FIG. 6 is later than time t2 in FIG. 5 with respect to time t1. The electronic shutter has been ON (opened) after time t6.

At time t3 that is a terminating moment of the first frame, all the charges stored on the CCD are transferred to the vertical transfer register of the imaging circuit 13. The charges are further transferred to the horizontal transfer register of the imaging circuit 13 and read out.

As disclosed, an image signal for the charges stored from time t6 to time t3 is read out at a read timing a1 as illustrated in READ TIMING; and hence the period from time t6 to time t3 is an exposure period 8. The higher the shutter speed, the shorter the exposure period 8.

After time t3, the MPU 15 controls the pixel-shift mechanism 12 via the driver 17 so that the light incident to the CCD is shifted by one line in the vertical direction, as illustrated in PIXEL-SHIFT TIMING of FIG. 6.

The MPU 15 also controls the shutter mechanism 11 via the driver 16 to shut out the light from being incident to the CCD at time t7 after time passes the same period as the exposure period 8, or the exposure period 9. The light is prevented from being incident to the CCD at and after time t7.

Charges for the second frame are stored on the CCD of the imaging circuit 13 for the period from time t3 to time t7. The charges are kept at time t7 because no light is incident to the CCD after time t7, so that no charges are stored on the CCD, thus causing no overflow, resulting in no discharging operation.

All the charges that have been stored on the CCD are transferred to the vertical transfer register at time t7 at which the second frame terminates under the control by a timing signal fed by the TG 18. The charges are further transferred to the

horizontal transfer register and read out.

As disclosed, an image signal for the charges stored from time t3 to time t7 is read out from the imaging circuit 13 at time t5, or a read timing a2 as illustrated in READ TIMING; and hence the period from time t3 to time t7 is an exposure period 9 as illustrated in EXPOSURE TIMING, by the mechanical shutter whose timing is illustrated as MECHANICAL SHUTTER TIMING.

The image signals for the fist and the second frames are supplied to the signal processor 19 and combined as an output composite imaging signal, as illustrated in SIGNAL PROCESSING 5.

In this embodiment, the displacement "d" of the image signals in time for the fist and the second frames corresponds to the exposure time 8 from time t6 to time t3, being shorter than that shown in FIG. 5, thus further avoiding blurry photos.

Next, the operation as the third preferred embodiment of the solid-state imaging apparatus according to the present invention will be described.

In the first and the second embodiments shown in FIGS. 5 and 6, the optical low-pass filter of the pixel-shift mechanism 12 is rotated by the angle "i" between the positions 21a and 21b, as shown in FIG. 4, for pixel-shifting at time t3 that is the starting moment of the second frame.

Compared to these embodiments, in the third embodiment, the optical low-pass filter of the pixel-shift mechanism 12 starts to rotate at time ta within the exposure period 8 just before time t3, and stops at time tb within the exposure period 9, as shown in FIG. 7. The illustration in (a) of FIG. 7 corresponds to that of EXPOSURE TIMING in FIG. 6. The period T1 from time ta to time t3 and the period T2 from time t3 to tb are preferably equal to each other, but not a must.

As disclosed, rotation of the optical low-pass filter of the pixel-shift mechanism 12 over the exposure periods 8 and 9 further avoids blurry photos.

The present invention is not limited to the embodiments disclosed above.

The electronic shutter is employed in the embodiments for

exposure for the first frame. However, the mechanical shutter can be employed for exposure for the first frame.

The embodiments combine the image signals for two successive frames. However, image signals for two successive fields can be combined for obtaining a composite image signal.

Not only a still image but also a moving picture can be processed by the present invention.

Image scanning in the embodiments is a progressive scanning-type. However, the present invention can employ an interlace scanning-type image sensing apparatus.

As disclosed above, according to the present invention, the image sensing device is exposed to light from an object by a shutter, provided between the object and the solid-state image sensing device, for a first exposure period and a second exposure period that directly follows the first exposure period. The first and the second periods are the same length in time. Each exposure period for exposing the solid-state image sensing device to the light corresponds to one frame or one filed of the object. A passage of the light that has passed the shutter and incident to the solid-state image sensing device is shifted in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period. Image signals converted for the first and the second exposure periods are combined to generate a composite image signal.

Thus, the present invention offers a pixel-shifting function with less blurry photos for solid-state image sensing apparatus.

Moreover, according to the present invention, the passage of light incident to the solid-state image sensing device can be shifted for a period from a moment in the first exposure period to another moment in the second exposure period.

This arrangement offers a pixel-shifting function with less blurry photos at high shutter speed for solid-state image sensing apparatus.

WHAT IS CLAIMED IS:

1. An image sensing apparatus comprising:

a solid-state image sensing device to convert light from an object into an image signal;

a shutter, provided between the object and the solid-state image sensing device, to expose the solid-state image sensing device to the light for a first exposure period and a second exposure period that directly follows the first exposure period, the first and the second periods being the same length in time, each exposure period for exposing the solid-state image sensing device to the light corresponding to one frame or one filed of the object;

a shift mechanism, to shift a passage of the light that has passed the shutter and incident to the solid-state image sensing device in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period; and

a processor to combine image signals converted for the first and the second exposure periods to generate a composite image signal.

2. The apparatus according to claim 1, wherein the shift mechanism shifts the passage of light for a period from a moment in the first exposure period to another moment in the second exposure period.

3. The apparatus according to claim 1, wherein the shift mechanism includes an optical low-pass filter that rotates between two predetermined positions to shift the passage of light in the predetermined direction.

4. A method of image sensing using a solid-state image sensing device for converting light from an object into an image signal, the method comprising the steps of:

exposing the solid-state image sensing device to the light

for a first exposure period and a second exposure period that directly follows the first exposure period, the first and the second periods being the same length in time, each exposure period for exposing the solid-state image sensing device to the light corresponding to one frame or one filed of the object;

shifting a passage of the light incident to the solid-state image sensing device in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period; and

combining image signals converted for the first and the second exposure periods to generate a composite image signal.

5. The method according to claim 4, wherein the shifting step includes the step of shifting the passage of light for a period from a moment in the first exposure period to another moment in the second exposure period.

ABSTRACT OF THE DISCLOSURE

Light from an object is incident to an image sensing device and converted into an image signal. The image sensing device is exposed to the light by a shutter, provided between the object and the solid-state image sensing device, for a first exposure period and a second exposure period that directly follows the first exposure period. The first and the second periods are the same length in time. Each exposure period for exposing the solid-state image sensing device to the light corresponds to one frame or one filed of the object. A passage of the light that has passed the shutter and incident to the solid-state image sensing device is shifted in a predetermined direction with respect to the solid-state image sensing device at least in the second exposure period. Image signals converted for the first and the second exposure periods are combined to generate a composite image signal.

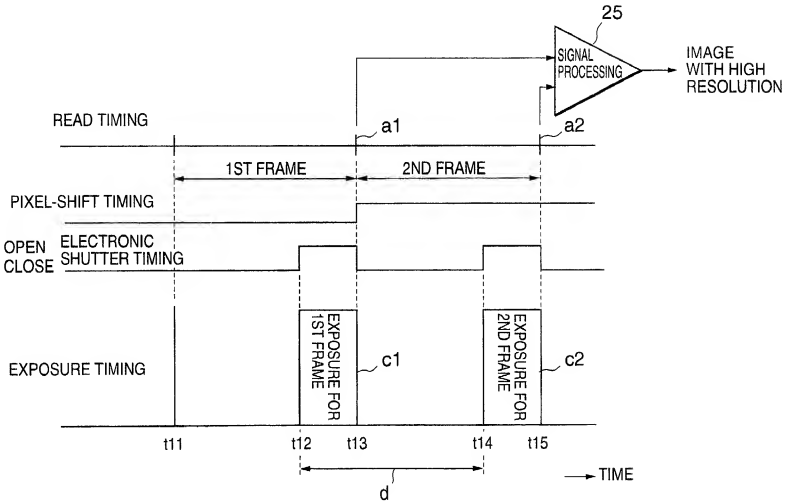

FIG.1 (RELATED ART)

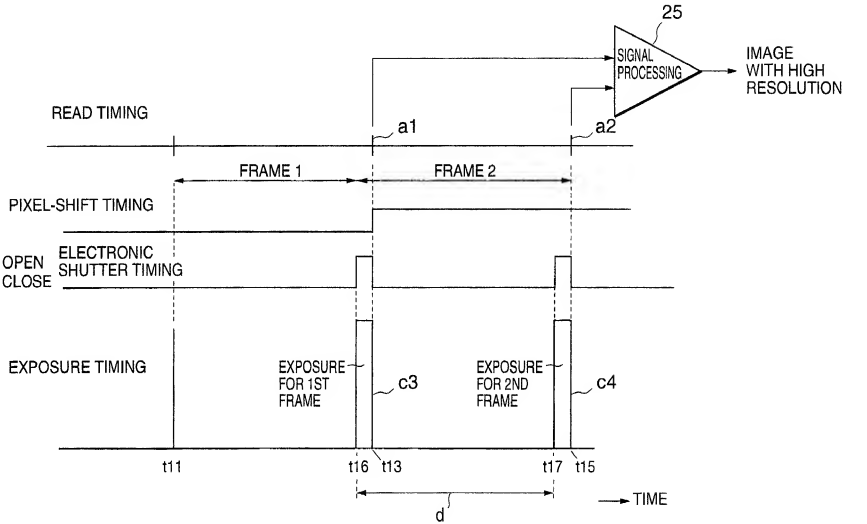

FIG.2 (RELATED ART)

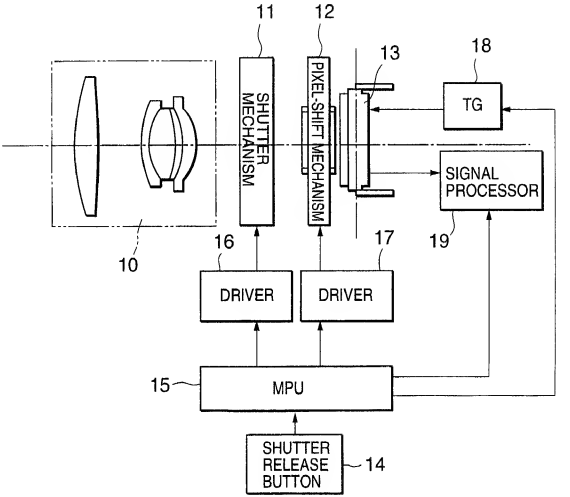

FIG.3

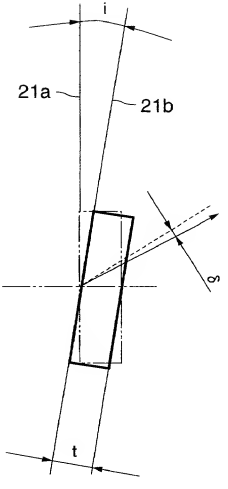

FIG.4

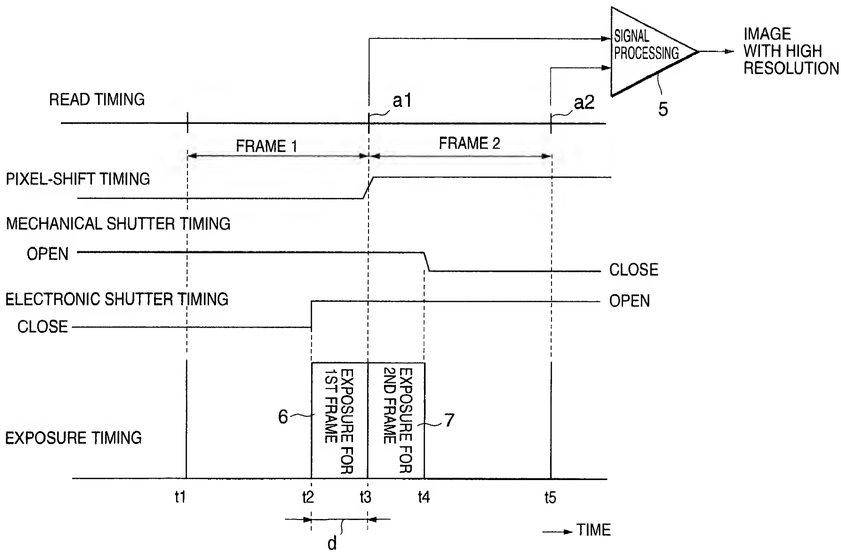
READ TIMING
a1
a2
FRAME 1
FRAME 2
PIXEL-SHIFT TIMING
MECHANICAL SHUTTER TIMING
OPEN
CLOSE
ELECTRONIC SHUTTER TIMING
CLOSE
OPEN
EXPOSURE TIMING
EXPOSURE FOR 1ST FRAME
EXPOSURE FOR 2ND FRAME
6
7
t1
t2
t3
t4
t5
d
TIME
SIGNAL PROCESSING
5
IMAGE WITH HIGH RESOLUTION

FIG.5

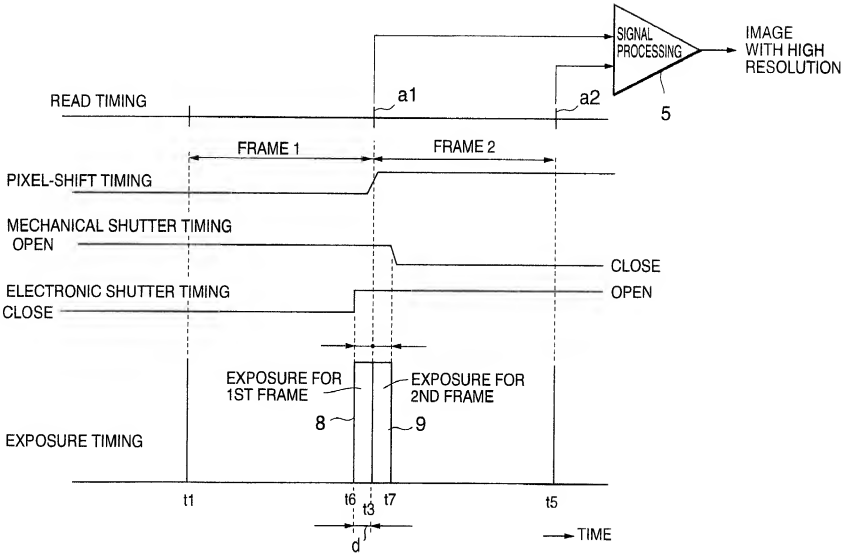

FIG.6

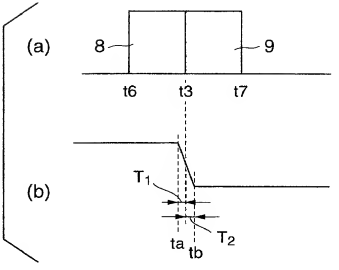

FIG.7

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below next to our names.

We believe we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled:

SOLID-STATE IMAGE SENSING APPARATUS AND METHOD OF IMAGE SENSING

the specification of which

_X_ is attached hereto.

___ was filed on _____ as Application Serial No. _____ and was amended on _____.

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

We hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

			Priority Claimed	
Number	Country	Date Filed	Yes	No
1999-264018	Japan	September 17, 1999	X	

English Language Declaration

We hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Ser. No.	Filing Date	Status

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As named inventors, we hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Edward G. Greive (Reg. No. 24,726); Reese Taylor (Reg. No. 22,325); Phillip L. Kenner (Reg. No. 22,353); Donald J. Bobak (Reg. No. 27,182), Ray L. Weber (Reg. No. 26,519), Rodney L. Skoglund (Reg. No. 36,010), Richard B. O'Planick (Reg. No. 29,096), Joseph G. Curatolo (Reg. No. 28,837), Andrew B. Morton (Reg. No. 37,400), Arthur M. Reginelli (Reg. No. 40,139), Shannon V. McCue (Reg. No. 42,859), Michael F. Morgan (Reg. No. 42,906), Salvatore A. Sidoti (Reg. No. 43,921), John J. Cunniff (Reg. No. 42,451); and Mark L. Weber (Reg. No. 46,069)

English Language Declaration

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